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1 INTRODUCTION

This report is submitted to the National Radio Systems Committee's Digital Audio Broadcasting Subcommittee from its Evaluation Working Group (EWG) in accordance with procedures that were established by the Subcommittee during meetings in 1999.

In summary:

- The EWG developed evaluation criteria and a System Evaluation Guidelines document that delineated the manner in which evaluations would be conducted;
- The basis for conducting tests and reporting results by a proponent were contained in two other NRSC DAB Subcommittee documents: one on laboratory tests, the other on field tests;
- The EWG, in designing the basis for its evaluations, developed a two dimensional table that arrayed the individual tests in the laboratory and field test guidelines documents with the ten basic evaluation criteria agreed upon;
- IBOC system proponents agreed to tender submissions on December 15, 1999;
- For each submission, an evaluation report (such as this one) would be developed;
- The NRSC's evaluation would be a comparison of the IBOC system(s) performance with the current performance of analog radio in the FM and AM broadcasting bands.

The Chairman expresses his hearty thanks to the 20 or so members of the EWG. An enormous amount of work was done, on a voluntary basis for most of the members, since early March 1999. The EWG membership included representatives of the broadcasting industry, the receiver manufacturing industry, the proponent organizations, and staff and consultants from NAB and CEA. With respect to the last category, special thanks goes to David Layer of NAB for carrying the brunt of the development of the documentation, taking care of the minutes of the telcon and full meetings of the working group, and contributing significantly to the analysis.

This report is organized as follows:

- Introduction: this section briefly reviews the process and events leading up to the generation of this evaluation report;
- Conclusion: a statement of the EWG's conclusions regarding the LDR IBOC submission including suggestions for future work;
- Discussion of findings: a detailed presentation of the data submitted, analysis performed, and conclusions reached, organized according to evaluation criteria established by the EWG;
- Appendices: supplemental information including analyses performed by the EWG during the course of its evaluation.

1.1 NRSC DAB SUBCOMMITTEE GOALS AND OBJECTIVES

The NRSC's DAB Subcommittee established goals and objectives on May 14, 1998 for the work to be done by it as a result of the re-activation of the Subcommittee (see Appendix A for the complete Goals and Objectives statement).

What the primary objective is:

The purpose of the current NRSC effort is to determine if current generation IBOC technology is a significant improvement over the analog systems currently in use. In other words, the evaluative quest is to determine if the current state-of-the-art of IBOC technology merits the conclusion that continuing to pursue IBOC technology, through all its technical and regulatory ramifications, is in the interest of U.S. listeners.

What is not an objective of the current work:

The work that has been done by the Subcommittee since mid-1998 has not dealt in any way with comparing the performances among different IBOC systems. This is due primarily to the fact that there have been no comparative tests (neither planned nor conducted) between different systems as would be necessary for valid comparisons to be made.

1.2 EVALUATION PROCESS DECISIONS MADE

From mid-1998 up to and including a meeting of the NRSC DAB Subcommittee that took place on April 17, 1999, several important decisions were made that established the construct of the overall evaluation process. These are summarized in this section.

1.2.1 Test guidelines would be established

The NRSC developed detailed laboratory and field test guidelines, which would explain to proponents the tests and information the NRSC deemed necessary for evaluating IBOC systems. These were developed by the DAB Subcommittee's Test Guidelines Working Group, Mr. Andy Laird, Chairman, during the second half of 1998 and early in 1999. They were approved by the Subcommittee in early 1999 (and are included with this report as Appendices B and C).

In construct, the recommended test protocols in the Guidelines documents were similar to those from an earlier EIA/NRSC DAB test process (conducted during the 1994-95 time frame), refined from then and dealing solely with testing of IBOC systems. The various test protocols include ways of eliciting IBOC system performance and the effects of the IBOC digital carriers on its host and adjacent channel analog (and digital) signals, and vice versa.

1.2.2 Formation and functioning of the Evaluation Working Group

In early 1999 the EWG was established, having its first meeting in early March 1999. An initial report was submitted to the Subcommittee at its April 1999 meeting in the form of the first version of a System Evaluation Guidelines document (complementary to the test guidelines documents mentioned

above). Subject to the incorporation of a few points of modification, the document was approved at the April 17th meeting (see Appendix D).

The EWG then developed ten (10) system evaluation criteria. These covered, at a high level directly related to broadcasting, those areas upon which the comparison with analog radio broadcasting would be based.

The working group also developed a cross-reference table between all the individual test protocols of the laboratory test and field test guidelines documents and each of the 10 evaluation criteria. This work was completed subsequent to the April 17th Subcommittee meeting, and the resulting table is being used in the evaluation of this current submission by LDR (see Appendix E).

1.2.3 Agreements on IBOC system scope and NRSC reporting of its evaluations

Five important provisions were agreed to at the April 17th Subcommittee meeting that bear on the submission of information to the NRSC DAB Subcommittee and on the reporting of the evaluation:

1. ***Complete hybrid (IBOC) system:*** any submission must document a full system, that is, one that is capable of IBOC operation in both the AM and FM broadcasting bands.
2. ***Data on an "all digital" system not evaluated at this time:*** although the ultimate objective for terrestrial radio broadcasting is likely to be full conversion to digital transmission, it is recognized that this will take many years as the conversion of thousands of stations takes place. Therefore, even though some proponents are working on "all digital" designs as part of their efforts, a decision was made to limit the current evaluation to the more pressing (and presumed more difficult) "hybrid IBOC" aspect of the conversion.
3. ***Only the performance of the IBOC system will be evaluated:*** several aspects of IBOC implementation are not to be evaluated, for example, the extent of transmitter conversion required and the expected cost of receivers. In summary, the technical and performance aspects of the system are to be evaluated. This includes the performance of the digital carriers as well as the impact the digital carriers have on its own host analog signal as well as on adjacent channel signals.
4. ***The NRSC will generate a separate report for each system submitted:*** in line with the decision to evaluate with respect to analog performance, and not to compare performance among digital systems, a separate evaluation report will be produced for each system for which system descriptions and data are submitted. This report, thus, deals exclusively with the LDR system in comparison with today's AM and FM modulation in their respective broadcasting bands.
5. ***Submission date - December 15, 1999:*** December 15, 1999 was agreed to by the proponents as the submission date for system descriptions and test data at the April 17, 1999 Subcommittee meeting.

On December 8, 1999, LDR informed the NRSC that it would be unable to make a submission on December 15, 1999, and instead would like to make a submission on January 24, 2000, coinciding with the comment deadline in the FCC's NPRM on terrestrial DAB. The DAB Subcommittee agreed to accept a submission from them on that date, and in addition, another proponent (USADR) was also given an additional two week submission "window," following the 1/24/00 LDR submission date. (USADR tendered its submission on December 15, 1999.)

1.3 MUCH WORK DONE; MUCH WORK LEFT TO DO

The DAB Subcommittee and its Test Guidelines Working Group have expended considerable effort in identifying the tests (specified in the Field Test and Lab Test Guidelines) that a proponent needs to perform, in order for the NRSC to be able to determine if a system is significantly improved over analog services. While some tests may be more vital in achieving this end than others, they all play a part in the process – each specified test is important and offers a unique insight into system performance.

A comparison of the test results which LDR has included in its submission with what is requested in the guidelines reveals that a substantial amount of information important to this evaluation has not been provided. LDR, at the time of its submission, indicated that due to time constraints involved with meeting internal system development objectives, its submission would include data taken only from its existing test program. Even though the specific tests detailed in the NRSC test guidelines were not performed, the LDR submission is valuable in helping the DAB Subcommittee work towards its present goal of comparing IBOC performance to analog system performance. It represents a considerable effort on the part of the proponent as well as providing the most complete technical “glimpse” of its system yet offered to the industry.

A comparison of the tests included in LDR’s submission with the tests specified in the NRSC’s Lab and Field Test Guidelines indicates the following number of tests were conducted. For FM lab tests, of the 67 specified in the guidelines, at least partial results were submitted for 5. For FM field tests, of the 12 tests specified in the guidelines, partial results for 4 were submitted. For AM lab tests, of the 25 specified tests, partial results on 5 were submitted. Finally, for the AM field tests, of the 8 specified tests, partial results for 0 were submitted.

The evaluation described in this report focuses on the information which was provided, and in some instances notes the absence of important data or factors not included in a test which, if present, would have offered additional valuable (if not vital) information. Clearly, additional information will be needed before the EWG, and ultimately the DAB Subcommittee, can be in a position to establish with technical rigor whether IBOC is a significant improvement over today’s analog services. This report represents the very best efforts of the EWG to evaluate the data submitted by LDR in light of the fact that specific NRSC test guidelines were not followed.

2 CONCLUSION

The basic conclusion: the “state-of-the-art” for IBOC technology indicates the reasonable probability of substantial improvement for broadcast listening compared to current analog performance in the AM and FM broadcasting bands.

LDR’s submission should be considered as a “sample point” to aid in determining whether IBOC “state-of-the-art” is good enough to have interested parties in the U.S. believe that this avenue for the implementation of digital radio is the path to pursue. The EWG notes that improvements in IBOC system performance are likely as the system development process continues.

Also, as noted elsewhere in this report, a significant number of the recommended tests from the Subcommittee’s laboratory and field test guidelines were neither conducted, nor reported, nor was there an adequate substituted test procedure that would permit us to evaluate results according to one or more of the ten agreed upon evaluation criteria.

LDR’s reported test results were primarily subjective audio listening assessments. While useful, the lack of objective laboratory test results and objective field test results prevented us from conducting a careful evaluation of system performance. The subjective listening test results supplied indicated better performance of the IBOC system than that of the analog performance being compared. Even here, however, there was some concern about the subjective test procedure used.

Therefore, the basic conclusion stated above is one that should be considered to be heavily qualified. This is because the EWG was unable to assess performance under some of the evaluation criteria with adequate engineering credibility. This is true more for the AM IBOC system than for the FM IBOC system, since very little AM IBOC information was provided.

Based upon this evaluation, the EWG is optimistic that LDR is on the proper track to develop IBOC DAB systems with the potential to significantly improve AM and FM radio broadcasting in the U.S. Encouragement is hereby given to LDR that it continue to develop its systems and test them in accordance with independent test procedures crafted in cooperation with the broadcast and consumer electronics industries.

3 DISCUSSION OF FINDINGS

In this section, the details of LDR's submission to the NRSC are presented, organized with respect to how each part of the submission relates to the EWG's 10 evaluation criteria. After presenting the data, a review of the EWG analysis followed by the conclusions which were arrived at are then given.

Note that since the tests and results described in the LDR submission were organized differently from the DAB Subcommittee's test guidelines documents, the first step in this process was for the EWG to determine how the submitted information corresponded to the tests specified in the guidelines (Appendix F). In the sections which follow, slightly modified versions of the tables in Appendix F are presented for each criteria, indicating for each submitted result the location of data/graph information (in the submission), any corresponding audio recordings submitted, and how that result would be compared against the existing analog service (indicated in the "analog benchmark" column).

3.1 Criteria used for evaluation

The EWG established 10 criteria to use for evaluating IBOC submissions. These criteria fall into two general categories: "IBOC receiver" results, which apply to data obtained directly from the IBOC receiver (*e.g.*, unimpaired audio quality of an IBOC signal, service area and durability of the IBOC signal, etc.); and, "Analog receiver" results, which address the compatibility of the IBOC signal with existing analog receivers.

Table 1 lists the evaluation criteria according to category. Refer to Appendix E for a detailed description of each criterion, as well as for a matrix which illustrates which tests (contained in the test guidelines) have a bearing upon which criteria.

Table 1. EWG evaluation criteria

IBOC RECEIVER RESULTS	ANALOG RECEIVER RESULTS
Audio quality	Host analog signal impact
Service area	Non-host analog signal impact
Durability	
Acquisition performance	
Auxiliary data capacity	
Behavior as signal degrades	
Stereo separation	
Flexibility	

3.2 FM IBOC system evaluation – findings

Since receiving the LDR submission on January 24, 2000, the EWG has undertaken an extensive review and analysis of the FM IBOC system test results and information presented. The results of this review are presented here in detail, organized according to evaluation criteria.

3.2.1 Criterion 1 – Audio quality

Table 2 lists the test results submitted by LDR pertaining to audio quality of their FM IBOC system. In this context, audio quality refers to the *unimpaired* audio quality of the system i.e. the audio quality absent any channel impairments or interferers.

Table 2. FM IBOC test results submitted by LDR pertaining to audio quality

TEST NO. (GUIDELINES)	DATA/GRAPHS	AUDIO RECORDINGS	BENCHMARK	COMMENTS
K2 (lab) – DAB quality – subjective assessment report of unimpaired IBOC audio quality vs. analog FM	<ul style="list-style-type: none"> • Fig. 1 (Appendix F.3, pg. 5) – Participants' ACR responses (averaged) • Fig. 2 (Appendix F.3, pg. 6) – Participants' ACR responses (by audio material) 	Cut 5 (Multi-streaming PAC at 128 kbps) Cut 7 (Multi-streaming PAC at 64 kbps)	<ul style="list-style-type: none"> • Included with submission – (and used for subjective evaluation) refer to audio cuts 1 (CD source), 3 (FM reference) 	<ul style="list-style-type: none"> • Audio material - Critical audio cuts listed in Table 1 of Appendix F.3. • Subjective evaluation performed on DAB recordings as well as FM reference and CD source • PAC recordings may or may not have been passed through an IBOC system.

While LDR has provided a subjective evaluation of unimpaired audio quality as requested in the test guidelines, there are a number of differences between what was submitted and what the NRSC requested in this regard. Ultimately, these differences make it difficult to interpret the results presented, and the EWG is unable to endorse the conclusions presented by LDR in their submission.

Conclusion: based solely on the subjective evaluation offered, the LDR FM IBOC audio appears to be an improvement over analog FM, but the nature of this improvement is not understood and needs to be investigated more fully.

3.2.2 Criteria 2, 3 – Service area, durability

Table 3 lists the test results submitted by LDR pertaining to service area and durability of their FM IBOC system. These two criteria have been combined in this section because they share the same list of tests (from the test guidelines) from which conclusions can be drawn.

The EWG intended to evaluate these criteria separately for IBOC audio and IBOC auxiliary data capacity. LDR submitted no information about the auxiliary data aspects of their system, so this evaluation is limited to consideration of IBOC audio performance.

Table 3. FM IBOC test results submitted by LDR pertaining to service area and durability

TEST NO. (GUIDELINES)	DATA/GRAPHS	AUDIO RECORDINGS	BENCHMARK	COMMENTS
B3 (lab) – AWGN, multipath fading channel, no interferers	• Fig. F1-1 (pg. 3) – Signal quality as a function of the receiver distance from the transmitter		• <u>Included with submission</u> – (and used for subjective evaluation) FM in static channel, FM with fast fading also included in Fig. F1-1 along with IBOC data.	• <u>Audio material</u> - Critical audio cuts listed in Table 1 of Appendix F.3.
B4 (lab) – AWGN, multipath fading channel, 1st adj. channel interferer	• Fig. F1-2 (pg. 7) – Signal quality as a function of the receiver distance from the transmitter w/1st adj. interferer • Appendix F.4, Table 7 – Performance of LDR IBOC system subjected to 1st adj. chnl. and fast rural fading		• <u>Included with submission</u> – (and used for subjective evaluation) FM with 1st adj. channel interference also included in Fig. F1-2 along with IBOC data.	• Noise not added; signal strength reduced instead • Mobile receivers only used in fading tests
B1,2 (field) – Strong signal with low interference – low and strong multipath	(none)	Cut 9 (Field test demonstration audio)	• None – no impairment observations made, no corresponding analog audio	• Demonstration of multistreaming PAC at 128 kbps • This data would seem to be unusable.
C 1,3 (field) – Single interferer at, above FCC limit				

The results presented by LDR are subjective evaluations. While valuable and somewhat encouraging, these results are not sufficient for the EWG to arrive at definitive conclusions regarding service area and durability.

Conclusions – service area and durability: presented data is encouraging but more information is needed.

3.2.3 Criterion 4 – Acquisition performance

LDR did not submit test results pertaining specifically to the acquisition performance of its FM IBOC system. Furthermore, the provided system description information did not address the issue of acquisition performance.

Conclusion: EWG analysis is inconclusive due to lack of information.

3.2.4 Criterion 5 – Auxiliary data capacity

LDR did not submit test results pertaining specifically to the auxiliary data capacity of its FM IBOC system. Furthermore, the provided system description information did not address the issue of auxiliary data capacity.

Conclusion: EWG analysis is inconclusive due to lack of information.

3.2.5 Criterion 6 – Behavior as signal degrades

LDR did not submit test results pertaining specifically to the FM IBOC system behavior as signal degrades. In the system description portion of their submission, LDR indicates that their multi-streaming technology provides for "...graceful degradation of the digital audio signal."¹

Conclusion: EWG analysis is inconclusive due to lack of information.

3.2.6 Criterion 7 – Stereo separation

While it would have been theoretically possible to perform a preliminary analysis on this aspect of system performance based on some of the audio files submitted, the EWG elected not to perform this analysis.

Conclusion: EWG analysis is inconclusive due to lack of information.

3.2.7 Criterion 8 – Flexibility

In their submission, LDR describes an "all-digital" IBOC technology to complement its hybrid design, and offers additional performance and service benefits.² Its system is also expected to provide support for auxiliary data services, however its submission does not elaborate on this.

Conclusion: the amount of flexibility which this system will support cannot be established at this time, due primarily to the fact that the system is still being tested and refined. By its very nature, IBOC technology involves tradeoffs between coverage, robustness, and flexibility. Only when the final system parameters which best balance these parameters are chosen will it be possible to competently judge the flexibility of the system.

3.2.8 Criterion 9 – Host analog signal impact

Table 4 lists the test results submitted by LDR pertaining to host analog signal impact of its FM IBOC system.

¹ See LDR submission, part III, pg. 3.

² See LDR submission, Appendix D, pg. 3.

Table 4. FM IBOC test results submitted by LDR pertaining to host analog signal impact

TEST NO. (GUIDELINES)	DATA/GRAPHS	AUDIO RECORDINGS	BENCHMARK	COMMENTS
L1 (lab) – IBOC “digital-to-host analog” compatibility performance – host analog main channel audio, linear channel	<ul style="list-style-type: none"> • Appendix G, Fig 1a, 1b (pg. 10) – Combined and expert listener overall responses • Appendix G, Fig 2a, 2b (pgs. 11, 12) – Audio quality ratings by receiver and multipath conditions • Appendix F 4, Table 3 (1st table 3, pg. 7) – ACR MOS by sound sample • Appendix F 4, Fig. 1 (pg. 6) – ACR MOS vs. avg. RF signal level (static cond.) 	(none)	<ul style="list-style-type: none"> • Included with submission – (and used for subjective evaluation) host signal with digital sidebands removed • None – no corresponding audio without IBOC sidebands recorded 	<ul style="list-style-type: none"> • 5 analog receivers used • IBOC carriers turned on and off for these tests • 4 analog receivers used • Subj. eval. vs. signal strength – IBOC carriers always on
L2 (lab) – IBOC “digital-to-host analog” compatibility perf. – host analog main chan. audio, fading chan.	(see Appendix G Data/Graphs for test L1 above)	(none)	<ul style="list-style-type: none"> • Included with submission – (and used for subjective evaluation) host signal with digital sidebands removed • None – no corresponding audio without IBOC sidebands recorded 	<ul style="list-style-type: none"> • 5 analog receivers used • IBOC carriers turned on and off for these tests
* Host analog main channel audio performance with fading	• Appendix F 4, Table 3 (2nd table 3, pg. 9) – ACR MOS by sound sample	(none)		<ul style="list-style-type: none"> • 2 mobile receivers used (in fading tests only); 4 non-mobile receivers used
* Host analog main channel audio performance with 1st adj. interference	• Appendix F 4, Tables 4, 5 (pgs. 10, 11) – ACR MOS w/1st adj. chan. interference	(none)		<ul style="list-style-type: none"> • Subj. eval. vs. signal strength – IBOC carriers always on
* Host analog main channel audio performance vs. output SNR	• Appendix F 4, Table 6 (pg. 12) – ACR MOS vs. SNR			

The results presented by LDR are subjective evaluations. While valuable and somewhat encouraging, these results are not sufficient for the EWG to arrive at definitive conclusions regarding host analog signal impact.

Specifically, no audio recordings were submitted which would have allowed the EWG to determine whether or not the presence of the digital carriers was noticeable on the host audio signal for the receivers tested. Nor were any objective measurements of host audio S/N ratio presented demonstrating quantitatively any effect which the presence of the digital carriers may be having.

Conclusion: EWG analysis is inconclusive on this criterion due to lack of information. Additional measurements are needed to rigorously establish the effect that the digital carriers have on the analog host.

3.2.9 Criterion 10 - Non-host analog signal impact

LDR did not submit any test results pertaining to the how the FM IBOC system impacts on a non-host analog signal.

Conclusion: EWG analysis is inconclusive on this due to lack of information.

3.3 AM IBOC system evaluation – major findings

Since receiving the LDR submission on January 24, 2000, the EWG has undertaken an extensive review and analysis of the AM IBOC system test results and information presented. The results of this review are presented here in detail, organized according to evaluation criteria.

3.3.1 Criterion 1 – Audio quality

LDR did not submit any test results pertaining to the unimpaired audio quality of its AM IBOC system.

Conclusion: EWG analysis is inconclusive on this due to lack of information.

3.3.2 Criteria 2, 3 – Service area, durability

Table 5 lists the test results submitted by LDR pertaining to service area and durability of its AM IBOC system.

Table 5. AM IBOC test results submitted by LDR pertaining to service area and durability

TEST NO. (GUIDELINES)	DATA/GRAPHS	AUDIORECORDINGS	BENCHMARK	COMMENTS
B1 (lab) – AWGN, linear channel, no interferers	• Tbl. J-1 (pg. 6) – AM hybrid performance with AWGN (FER vs. RF S/N ratio)	(none)	• Analytical comparison to analog – estimate IBOC “digital TOA service area” by calculating analog field strength at digital TOA operating point, and compare this to analog protected contour	• Analog bandlimited to ± 4.5 kHz (all cases) • FER given for all 3 streams • For co-channel tests, both carriers are IBOC • Data from test H3 serves nicely as a benchmark for test D3 (lab) results below
C2 (lab) – IBOC system performance with special impairments – weak sig.	• Tbl. J-2 (pg. 7) – Receiver sensitivity (FER vs. RF signal level)			
D1 (lab) – IBOC “digital-to-digital” compatibility performance – linear chnl., w/co-chan. intf.	• Tbl. J-3 (pg. 8) – AM IBOC co-channel interference (FER vs. co-channel D/U)			
H3 (lab) – IBOC “analog-to-digital” compatibility performance – simultaneous upper and lower 1st adj. interferers	• Tbl. J-4 (pg. 10) – Performance with upper and lower analog 1st adj. interference (FER vs. 1st adj. D/U)			
D3 (lab) – IBOC “digital-to-digital” compatibility performance – linear chnl., w/simultaneous upper and lower 1st adj. interferers	• Tbl. J-5 (pg. 11) – Performance with upper and lower 1st adj. AM IBOC interference (FER vs. 1st adj. D/U)	(none)	• Measured results – refer to test H-3 results (included in submission) which are from same test as D-3 except using analog interferers (see supplemental graph in report)	• Both interferers are IBOC • FER given for all 3 streams • Analog band limited to ± 4.5 kHz
* D/11 (lab) – IBOC compatibility performance	• Tbl. J-6 (pg. 13) – Performance in presence of upper 1st and upper 2nd adj. AM IBOC interference (FER vs. 1st and 2nd adj. D/U)	(none)	• Analytical comparison to analog – estimate IBOC “digital TOA service area” by calculating analog field strength at digital TOA operating point, and compare this to analog protected contour	• Various combinations of 1st, 2nd adj. chnl. D/U tested • FER given for all 3 streams

* indicates test not specified by NRSC's test guidelines.

The submitted results, consisting of FER measurements versus various operating parameters, demonstrate the robustness of the different “streams” which make up the LDR digital waveform. Two of the tests, “D3” and “H3” (using the NRSC guidelines designations) lent themselves to direct comparison, the results of which are presented in Figure 1. This plot suggests that in the case of dual 1st adjacent interferers, the IBOC digital carrier energy (in the adjacent channels) is degrading the AM IBOC performance by a substantial amount (>10 dB) compared to the case where the interferers are solely analog carriers.³

³ Note that in the case of the analog interferers, these interferers have significantly reduced bandwidth (± 4.5 kHz) than would typical AM interferers (which would have a bandwidth of ± 10 kHz). Consequently, the actual performance difference between typical AM interferers and LDR AM IBOC interferers is unknown.

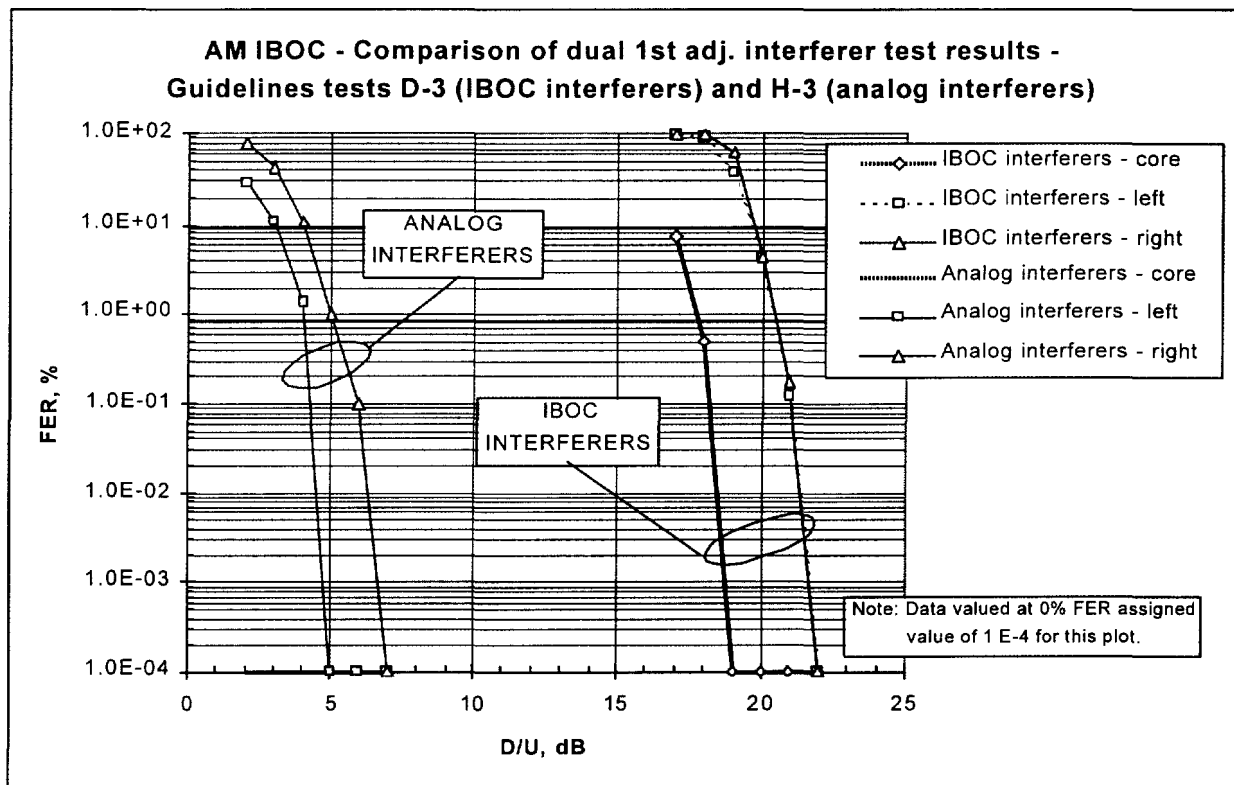


Figure 1. Comparison of dual 1st adj. interferer test results

This information, while interesting, when taken in isolation does little to help the EWG determine anything definitive regarding a comparison of service area and durability between LDR's AM IBOC and analog AM service.

Conclusion – service area and durability: more information is needed before conclusions can be drawn on these criteria.

3.3.3 Criterion 4 – Acquisition performance

LDR did not submit any test results pertaining specifically to the acquisition performance of its AM IBOC system.

Conclusion: EWG analysis is inconclusive on this due to lack of information.

3.3.4 Criterion 5 – Auxiliary data capacity

LDR did not submit any test results pertaining specifically to the auxiliary data capacity of its AM IBOC system.

Conclusion: EWG analysis is inconclusive on this due to lack of information.

3.3.5 Criterion 6 – Behavior as signal degrades

LDR did not submit any test results pertaining specifically to the FM IBOC system behavior as signal degrades. In the system description portion of their submission, LDR indicates that its AM system utilizes multi-streaming technology, which is described as providing for “...graceful degradation of the digital audio signal.”⁴

Conclusion: EWG analysis is inconclusive on this due to lack of information.

3.3.6 Criterion 7 – Stereo separation

While it would have been theoretically possible to perform a preliminary analysis on this aspect of system performance based on some of the audio files submitted, the EWG elected not to perform this analysis.

Conclusion: EWG analysis is inconclusive on this due to lack of information.

3.3.7 Criterion 8 – Flexibility

In their submission, LDR describes an “all-digital” IBOC technology which complements their hybrid design and offers additional performance and service benefits.⁵ Its system is also expected to provide support for auxiliary data services, however their submission does not elaborate on this.

Conclusion: The amount of flexibility which this system ultimately supports cannot be established at this time, due not only to the fact that the features allowing for flexible operation have not been reported on in the present submission, but also to the fact that the system is still being tested and refined. By its very nature, IBOC technology involves a number of tradeoffs between such aspects of performance as coverage, robustness, and flexibility. Only when the final system parameters which best balance these parameters are chosen will it be possible to competently judge the flexibility of the system.

3.3.8 Criterion 9 – Host analog signal impact

Normally when considering this criterion, the goal is to determine how the presence of the digital carriers affect the reception of the co-located analog “host” signal on existing analog receivers. Ideally, the impact will be slight; the EWG recognizes that it would be unrealistic to expect no impact due to the nature of IBOC system design. Indeed, one of the many challenges that IBOC designers face is how to trade off digital carrier coverage against impact caused to the host analog signal.

In their submission, LDR did not include any test results or information which would provide insight into host analog signal impact in the normal sense. One part of the system information portion of the submission does bear upon this criterion, specifically, the fact that the LDR AM IBOC system

⁴ See LDR submission, part III, pg. 3. While this comment was directed at their FM system, the EWG understands that it applies to their AM system, as well.

⁵ See LDR submission, Appendix I, pg. 9.

requires a reduction in bandwidth of the analog signal, from ± 10 kHz to ± 4.5 kHz. The EWG has some concerns about this requirement. However, some broadcasters may find this reduced bandwidth an acceptable tradeoff in a transition to digital services.

Conclusion: the EWG cannot conclude anything about the host analog signal impact performance of the LDR AM IBOC system due to a lack of information. However, there is some concern on the part of the EWG with respect to the reduction in analog signal bandwidth required by the AM IBOC system design.

3.3.9 Criterion 10 - Non-host analog signal impact

LDR did not submit any test results pertaining to the non-host analog signal impact of its AM IBOC system. As with host analog signal impact, ideally, the impact on non-host analog signals due to the IBOC digital carriers will be slight; the EWG recognizes that it would be unrealistic to expect no impact due to the nature of IBOC system design.

Conclusion: EWG analysis is inconclusive on this due to lack of information.

Appendix A – DAB Subcommittee Goals & Objectives



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5/14/98

DAB Subcommittee Goals & Objectives

(as adopted by the Subcommittee on May 14, 1998)

Objectives

- (a) To study IBOC DAB systems and determine if they provide broadcasters and users with:
- A digital signal with significantly greater quality and durability than available from the AM and FM analog systems that presently exist in the United States;
 - A digital service area that is at least equivalent to the host station's analog service area while simultaneously providing suitable protection in co-channel and adjacent channel situations;
 - A smooth transition from analog to digital services.
- (b) To provide broadcasters and receiver manufacturers with the information they need to make an informed decision on the future of digital audio broadcasting in the United States, and if appropriate to foster its implementation.

Goals

To meet its objectives, the Subcommittee will work towards achieving the following goals:

- (a) To develop a technical record and, where applicable, draw conclusions that will be useful to the NRSC in the evaluation of IBOC systems;
- (b) To provide a direct comparison between IBOC DAB and existing analog broadcasting systems, and between an IBOC signal and its host analog signal, over a wide variation of terrain and under adverse propagation conditions that could be expected to be found throughout the United States;
- (c) To fully assess the impact of the IBOC DAB signal upon the existing analog broadcast signals with which they must co-exist;
- (d) To develop a testing process and measurement criteria that will produce conclusive, believable and acceptable results, and be of a streamlined nature so as not to impede rapid development of this new technology;
- (e) To work closely with IBOC system proponents in the development of their laboratory and field test plans, which will be used to provide the basis for the comparisons mentioned in Goals (a) and (b);
- (f) To indirectly participate in the test process, by assisting in selection of (one or more) independent testing agencies, or by closely observing proponent-conducted tests, to insure that the testing as defined under Goal (e) is executed in a thorough, fair and impartial manner.

Appendix B – IBOC DAB System Test Guidelines – Part I – Laboratory Tests

(this document is available on the NRSC website)

Appendix C – IBOC DAB System Test Guidelines – Part II – Field Tests

(this document is available on the NRSC website)

Appendix D – IBOC DAB System Evaluation Guidelines

(this document is available on the NRSC website)

**Appendix E –
NRSC IBOC
System Evaluation Matrix**

EVALUATION CRITERIA DESCRIPTIONS – IBOC RECEIVER RESULTS

Audio quality – the fundamental audio quality of the IBOC system, all channel impairments aside. This assessment is to be made with respect to the audio quality of the existing analog broadcasting service as represented by the NRSC broadcast chain audio.

Service area – the geographical area surrounding the transmit station which can be expected to receive a listenable (usable) radio signal. Applied separately to IBOC audio and IBOC auxiliary data capacity (i.e. degree of correlation needs to be established).

Durability – characterized by an IBOC system design's ability to withstand interference from other radio signals (co-channel, 1st adjacent channel, and 2nd adjacent channel signals in particular) and to withstand the impairing effects of the RF channel. Applied separately to IBOC audio and IBOC auxiliary data capacity (i.e. degree of correlation needs to be established).

Acquisition performance – the characteristics of how a receiver “locks on” to a radio signal, including acquisition time (the elapsed time between tuning to a channel and when the audio on that channel is first heard), and audio quality following acquisition. Applies to both IBOC audio and IBOC auxiliary data capacity (in the latter case, performance metric is acceptable bit and/or frame error rate).

Auxiliary data capacity – characteristics of the data capacity supported by an IBOC system in excess of that needed to deliver the IBOC audio signal, including available throughput, nature of capacity (opportunistic versus continuously available), and transmission quality and durability through the channel (bit error rate and/or other relevant digital data transmission metrics as a function of impairments).

Behavior as signal degrades – how an IBOC system performs as its signal degrades, in particular, how abruptly the signal becomes unusable, and how the level of quality of the signal changes as the edge of coverage is approached. Note that, due to the complexities of RF signal propagation, “edge of coverage” performance may be experienced throughout a station's service area and is not restricted simply to regions near or beyond the theoretical protected contour.

Stereo separation – the amount of stereo separation present in the IBOC audio signal, and how it varies as a function of channel and received signal conditions.

Flexibility – represents the potential of an IBOC system to be adapted by broadcasters and manufacturers to meet the needs of listeners and consumers, both present and future. [Primarily addressed in system description portion of submission; test results not expected to provide direct evidence of system flexibility.]

EVALUATION CRITERIA DESCRIPTIONS – ANALOG RECEIVER RESULTS

Host analog signal impact – changes in performance of a host analog signal (main channel audio and any subcarriers) as a result of the presence of the IBOC digital signal energy associated with that host.

Non-host analog signal impact – changes in the performance of a (desired) analog signal (main channel audio only) as a result of the presence of interfering IBOC signals. Interfering signals of interest include co-channel, 1st, and 2nd adjacent channel signals, individually and in combinations.

[illegible]

FM IBOC System Evaluation Matrix – Lab Tests – rev. 4

		R E C E I V E R U N D E R T E S T								
		I B O C							A N A L O G	
TEST	DESCRIPTION	AUDIO QUALITY	SERVICE AREA	DURA- BILITY	ACQ. PERFORM.	AUX. DATA CAPACITY	BEHAVIOR AS SIGNAL DEGRADES	STEREO SEP	HOST SIGNAL IMPACT	NON-HOST SIGNAL IMPACT
D	IBOC "digital-to-digital" compatibility performance									
1)	Co-channel interference		✓	✓		✓	✓	✓		
2)	Single 1st-adjacent channel interference									
3)	Simultaneous upper and lower 1st-adjacent channel interference									
4)	Single 2nd-adjacent channel interference									
5)	Single 2nd-adjacent channel interference w/1st adj. channel interference									
6)	Simultaneous upper and lower 2nd-adjacent channel interference									
7)	Simultaneous upper and lower 2nd-adjacent channel interference with non-linearity									
E	IBOC "digital-to-digital" compatibility performance in a multipath fading channel									
1)	Co-channel interference		✓	✓		✓	✓	✓		
2)	Single 1st-adjacent channel interference									
3)	Simultaneous upper and lower 1st-adjacent channel interference									
4)	Single 2nd-adjacent channel interference									
5)	Single 2nd-adjacent channel interference w/1st adj. channel interference									
6)	Simultaneous upper and lower 2nd-adjacent channel interference									
7)	Simultaneous upper and lower 2nd-adjacent channel interference with non-linearity									